NOAA SCIENTIFIC SUPPORT MEMO

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Re.: Chemical Characterization and Environmental Fate of Jet Fuels with Specific Attention to JP-8

In response to the recent JP-8 release, I have prepared an overview of jet fuels and probable environmental fates to consider in evaluating the current spill. I hope this information will provide a prospective on jet fuels and jet fuel spills in the environment. General jet fuel information, specific information on JP-8 including an ADIOS2 (oil weathering model) output for JP-8, and a comparison with other fuel oils is provided.

General Characterization of Jet Fuel

In general, jet fuels are highly refined kerosene products. Jet fuels are blended from low sulfur or desulfurized kerosene and various light distillates generated from hydrocracking partially refined petroleum feedstocks. The end product must meet critical specifications including a very low freeze point (or pour point), smoke point, and aromatic hydrocarbon content (generally <20%). The smoke point characteristic of a fuel oil can be improved by a process called hydrotreating. Hydrotreating jet fuel results in converting unsaturated aromatic hydrocarbon compounds to saturated hydrocarbons such as alkylated naphthenes which have a lower carbon to hydrogen ratio and burn cleaner. Special additives are used in all jet fuels to meet users specifications such as storage stability. Additives are important components but represent only a very small fraction of the fuel oil mixture.

User specifications vary, and, as a result, a wide range in flash points (-10 to 60°C) exist within the general jet fuel classification. Jet fuels are often subdivided into two basic types: wide-cut gasoline-type and basic kerosene-

type. Wide-cut gasoline-type jet fuels such as USAF JP-4 contain gasoline and kerosene distillates; the resultant blend is highly flammable. Basic kerosene-type fuels such a commercial Jet A and military JP-5 have a narrow boiling point range and a higher flash point similar to generic kerosene (reduced flammability, reduced fire and explosive hazard). Safety considerations limit commercial and naval aircraft fuels to the later type. Civil Jet A and military JP-5 contain essentially the same petroleum distillates and differ only in the additives used.

Table 1 provides generic physical property data for a variety of fuel oils. The values shown are the median values collected and each value has been reduced to a single significant figure (a degree of precision which is more than accurate for response and hazard assessment). Table 1 clearly indicates that aviation gasoline (avgas not jet fuel) and automobile gasoline have the greatest fire and explosive hazard (lowest flash points) followed closely by wide-cut gasoline-type jet fuels (JP-4 and Jet B).

Table 1. Generic Physical Property Data for a Variety of Fuel Oils

Fuel	FP (1) (°C)	PP (2) (°C)	Gravity (3) (API)	Color
Aviation Gasoline(Avgas)	-50	-60	70	dyed green (4)
Gasoline Unleaded	-30	no data	no data	no data
JP-4	-10	-50	50	no data
Jet Fuel B	-10	-50	50	no data
Diesel, Grade 1-D (5)	40	-30	40	yellow to light amber
Kerosene, #1 Fuel Oil	40	no data	40	colorless to light brown
JP-6	40	no data	no data	no data
Jet Fuel A-1	40	-50	40	no data
JP-8	40	-50	40	colorless to light yellow
Gas Turb. Fuel, 1-GT	40	-20	40	no data
Jet Fuel A	50	-40	40	no data
JP-5	50	-50	40	colorless to light brown
Diesel, Grade 2-D (6)	60	-20	40	light amber
JP-7	60	-30	50	no data

(1) Flash point reported as median with only one significant figure accuracy.
(2) Pour point reported as median with only one significant figure accuracy.
(3) Gravity reported in degrees API with only one significant figure accuracy..
(4) Avgas 80-red, Avgas 115-purple, Avgas 100LL-blue, and Avgas 100-green. The values shown are for Avgas 100.
(5) Light diesel formulated for automobiles, etc.
(6) Heavier diesel formulation similar to #2 fuel oil.

Specific Information for JP-8

JP-8 jet fuel was developed as a jet fuel in response to problems encountered in use of JP-4 jet fuel. By the fall of 1996, JP-8 completely replaced JP-4 in the United States Air Force. JP-8 has a strong odor and is oily to the touch. Some 4.5 billion gallons are used by the US Air Force, the US Army, and NATO each year. JP-8 is also used to fuel heaters, stoves, tanks, and other vehicles in military service; and used as coolant for engines and other aircraft components. JP-8 is planned on being used at least until the year 2025 as the battlefield fuel for all U.S. military operations. JP-8 without several specific additives is essentially Jet A or commercial jet fuel.

Since JP-8 is a newer type of fuel, the hazards of the use of JP-8 are less fully known. OSHA & ACGIH have no promulgated exposure standards set for the use of JP-8. The Navy has a standard of 8 hours of PEL of 350 mg/m3 and 15 min STEL of 1800 mg/m3 (much of this information was found at www.JP-8.org). Workers have complained of smelling and tasting JP-8 many hours after cessation of the exposure. They have also reported dizziness, lightheadedness and skin problems.

While JP-8 is manufactured by a large number of international refiners, the majority contain some 220 different hydrocarbon constituents, and up to six performance additives that provide antioxidation, reduced metal deactivation, static dissipation, corrosion inhibition, and deicing. Ethylene glycol monomethyl ether (EM) is used to provide icing inhibition and typically represents 0.15% of the fuel volume. EM's water solubility is estimated at 100 ppm. EM may increase health exposure concerns, but remains a minor constituent. JP-8 is approximately 99.8% kerosene by weight.

JP-8: 50% paraffinic hydrocarbons.
-n-octane.
-n-nonane.

33% naphthalenes.

17% aromatic hydrocarbons.
-benzene (0.8%).
-touene (1.0%).
-p-, m-, o- xylenes (5.4%).
-trimthylbenzenes (6.6%).

0.2% 2- methoxyethanol.

(Reference, JP-8 Material Safety Data Sheet , Phillips 66, Aug 1995)

Fate of spilled JP-8 (Applicable to all Kerosene-based Jet Fuels)

Since JP-8 is a kerosene based fuel oil, it is relatively volatile and will evaporate if conditions allow. Having a boiling point range between that of gasoline and diesel, JP-8 will evaporate slower than gasoline. Spilled JP-8 in an open water environment which would allow maximum spreading would be expected to persist on the water surface for only a single day with the majority of the fuel lost to evaporation. With increasing sea-state, a larger fraction would be expected to disperse into the water column. ADIOS2 predicts that for a 100,000 gallon release in an open water with a 5 mph wind, dispersion would be less than 1% of the spill. For a 15 mph wind, dispersion would increase to 10% in the first 6 hours (see model outputs below). Dispersed fuel would be expected to biodegrade in a short period of time (days to weeks).

Clearly, if the spill is on land or into a confined waterways such a small pond or stream, the rate of evaporation would be significantly less and enhanced dissolution would be observed in underlying waters. If there is turbulent mixing such as in rapids or water passing over a weir, dispersion would be increased. It is impossible to model these conditions due to the number of variables such as variable fuel thickness and fuel penetration into organic debris and sediment/soils. Clearly, any fuel that escapes into an open water environment would persist for less than one additional day. JP-8 residual would be expected to persist in sediment for months to years depending on the concentration and specific environmental conditions.

ADIOS2 Model Output: Senario 1 - Open Water and Light Winds

```
Oil Name = JP-8
API = 45.4
Pour Point = unknown
Wind Speed = constant at 5 mph
Wave Height = computed from winds
Water Temperature = 60 deg F
Total Amount of Oil Released = 100,000 gal
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Hours Into Spill	Released gal		Evaporated percent		Dispersed percent		Remaining percent
1	100,000	-	1	-	<1	-	99
2	100,000		4		<1		96
4	100,000	-	14	-	<1	-	86
6	100,000		32		<1		68
8	100,000	-	53	-	<1	-	47
10	100,000		71		<1		29
12	100,000	-	82	-	<1	-	18

ADIOS2 Model Output: Senario 2 - Open Water and Moderate Winds

```
Oil Name = JP-8
API = 45.4
Pour Point = unknown
Wind Speed = constant at 15 mph
Wave Height = computed from winds
Water Temperature = 60 deg F
Total Amount of Oil Released = 100,000 gal
```

Hours Into Spill	Released gal		Evaporated percent		Dispersed percent		Remaining percent
2	100,000	-	10	-	1	-	89
3	100,000		22		2		75
4	100,000	-	38	-	5	-	58
5	100,000		53		7		40
6	100,000	-	64	-	10	-	26
7	100,000		72		12		16

Additional General information on Selected Jet Fuels

Jet A. A petroleum distillate blended from kerosene fractions and used in civil aviation. Standard operational fuel for commercial turboprop and turbojet aircraft in the US.

Jet A-1 (Turbo Fuel A-1). A petroleum distillate blended from kerosene fractions and is the standard operational fuel for civilian aviation requiring a low freezing point product. Jet A-1 is similar to Jet A except for a lower freezing point. Standard commercial fuel used on commercial international flights.

Jet B. A wide boiling-range petroleum distillate blended from gasoline and kerosene fractions. Operational fuel for US and NATO military aircraft and for many commercial turboprop and turbojet aircraft. Similar to JP-4 but with different additives.

JP-1, JP-2, and JP-3. Early US military jet fuels developed in the 1940's. Primarily wide-cut formulations and all are obsolete.

JP-4. The standard USAF wide-cut aviation turbine fuel prior to 1996. The general formulation is 65% gasoline-type and 35% kerosene-type hydrocarbons.

JP-5. Specially refined kerosene. Similar to Jet A but with additional additives to meet military specifications. Standard Navy and USCG jet fuel. This fuel was designed specifically to reduce safety and combat hazards on naval aircraft carriers.

JP-6. A higher kerosene fraction than JP-4 and with fewer impurities. The fuel was designed to have improved thermal stability properties and was used for certain supersonic aircraft such as high altitude, supersonic bombers. JP-6 is obsolete.

JP-7. A high flash point, special kerosene-refined fuel used in advanced supersonic aircraft. This fuel has enhanced combustion and thermal stability properties and developed specifically for use in very high performance, Mach 3 plus, aircraft.

JP-8. A kerosene modeled on Jet A-1. The fuel was formulated to address safety and combat concerns relative to the highly flammable USAF standard jet fuel, JP-4. Currently, JP-8 is the USAF and NATO Standard (see above for more information). JP-8 is also known as F-34, F-35, NATO-34, and NATO-35.

References

Allinson, J.P. 1973. Criteria for Quality of Petroleum Products. John Wiley and Sons, New York. 286 pp.

Environment Canada. 1994. Catalogue of Crude Oil and Oil Product Properties. Emergencies Science Division, Environmental Technology Centre, 3439 River Road, Ottawa, Ontario. (ASCII data Files)

Hughes, J.R. and N.S. Swindells. 1987. The Storage and Handling of Petroleum Liquids. Charles Griffin & Company Ltd., London. 332 pp.

Leffler. W.L. 1979 Petroleum Refining for the Non-Technical Person. PennWell Books, Tulsa, Oklahoma. 159 pp.

Disclaimer

Please note, this report was generated by the Science Support Coordinator in support of an emergency spill event. The information contained in this report has not undergone extensive review and is intended to provide real-time data to answer response questions. Please keep this in mind if you intend to use this information outside its original purpose.